MAINTENANCE MANAGEMENT IN THE CANADIAN MINING INDUSTRY -- AN EXECUTIVE SUMMARY

FINAL REPORT

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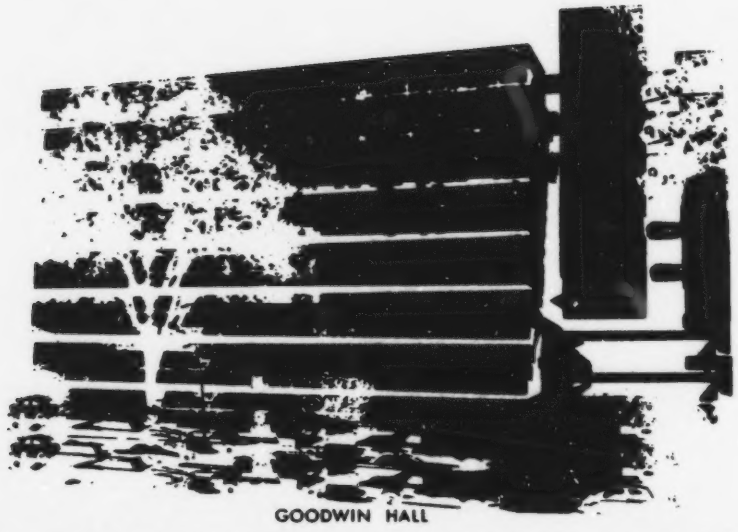

GOODWIN HALL

MINING ENGINEERING
QUEEN'S UNIVERSITY at kingston, ontario, canada

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Mining Engineering Department

Queen's University

Kingston, Ontario

MICROMEDIA

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FOREWORD

An attempt to develop maintenance awareness and maintenance management capability is hardly new to the Canadian mineral industry. In addition to work by competent mine managers in many organizations, there have been attempts to develop relevant courses in at least one Canadian university. Numerous industrial courses and a number of professional consultants active in the area also attest to the interest and perceived requirements. The regrettable point is that these efforts have not generated the major changes that now seem both desirable and profitable. If the recent CANMET state-of-the-art review brings about a change in this pattern it will represent a milestone indeed. Therefore, a brief outline of the background and of a few sequels to that project may be timely.

In early 1982 CANMET was attempting to establish an approach by which to review the state-of-the-art of maintenance in Canadian mines when it learned that a Masters candidate at Queen's University's Department of Mining Engineering was looking into the literature on maintenance to determine how a useful thesis in the area might be developed. The common interest resulted in a contract between CANMET and QUEEN'S UNIVERSITY that produced the report summarized here. It is both relevant and gratifying to the sponsor and the authors that those in the industry who participated in the review and have commented on the report have endorsed both the report and its methodology. However, at least one sequel to that work is also noteworthy.

The sequel of interest was a series of seminars conducted by the authors with CANMET approval to obtain an early and wide evaluation of the new results. In brief, the report had indicated that a major reduction of gross operating costs could be achieved in Canadian mines if significant changes in maintenance management could be effected. However, those conclusions were based on a fairly small sample and it might have been easy to regard them as academic observations. In the seminars the report, along with its methodology, was outlined to some 40 seminar representatives of about 30 companies or operations, in addi-

tion to those who were interviewed in the study. Unanimous endorsement was given both to the approach and to the results reported. Moreover, the seminar participants argued that the estimates of achievable savings, indicated by the report as being at least $100,000,000 per year across the industry, were too conservative.

In identifying a potential improvement of this magnitude it is usual and natural to ask how an oversight, error, or misdirection allowed the gap to develop. However, it would be grossly unfair to cloud the issues and to aggravate the problem by attempting to assess and assign any blame. The industry changed greatly over the decades in which the pattern developed. Moreover that same period was one in which all levels of management were thoroughly occupied by changes in labour relations, tax policies, social changes and inflation. It would have been remarkable, indeed, if some aspect of the industry had not received less attention than it deserved.

Other sequels to the review include: (a) changes in maintenance procedures now adopted by at least one company; (b) an upcoming all-Canadian meeting of Mine Maintenance Managers to determine the value and form that an organization of their group might adopt; and (c) endorsement of the aims of the review by the Mining Association of Canada. However, at least one serious problem still remains: how to initiate change now that its need is clearly recognized.

Two broad areas of the industry undoubtedly require development:

1) The personal/professional skills and attitudes that will be essential to the effective use of information - oriented maintenance management, and;

2) The commitment of individual companies or operations to the organizations and approaches with which more effective maintenance management can be established.

The problem, of course, is that each of these depends on the existence of the other. The first can be regarded as a

teaching/training/learning requirement that is industry-wide and includes both professional- and trade-level developments. The second is strictly an individual company or property issue. It is doubtful that CANMET has a direct role to play in either area.

One point is clear: that the first area is one in which there must be an industry initiative. The universities, technological institutes, technical schools and consultants all may be able to contribute to the development of means required for teaching the skills and developing the attitudes that will be required. However the costs will be too high for any one organization to bear in the current economy, especially since the materials developed will, generally, be usable by all. Moreover, neither the various teaching institutions nor the consultants can be expected to adopt an entrepreneurial attitude toward the new development products, (essentially teaching tools and courses) without a commitment from the industry as a whole. In addition it should be remembered that the relevant professional organization, the Canadian Institute of Mining and Metallurgy, is neither authorized to represent the industry (as opposed to the individual professionals in it) nor funded to sponsor the projected effort.

The approach proposed in the report would have the Mining Association of Canada and the Coal Association of Canada jointly sponsor a Mine Maintenance Development Program with, or without, independent executive direction. Admittedly, this would represent an extension of the traditional roles of the MAC and CAC. Alternatively, the issue involved is a policy matter of precisely the sort that these organizations might elect to handle.

It will be appreciated that the Maintenance Management Development Program outlined in the report was advanced without the experience noted above of the past year. If the proposal of the report were revised to reflect that new information at least one significant change would be made: the first stage, the Executive Direction stage,would be extended to permit illustrations of policy and organization implications of maintenance management development experienced in other industries. Also, a more specific proposal for the Program itself could be provided so that the pro-

bability of obtaining commitments to the concept would be much higher.

In any case, we remain convinced that, given reasonable support by the industry, the proposed Program could be implemented within about one year. Moreover, no foreseeable changes would raise the total cost of that implementation effort above about $100,000.

In that light, an economic evaluation is fairly simple: even under the most wildly extravagant approaches that could be conceived, the maximum cost of operating the indicated teaching/learning system could not exceed $10,000,000 per year across the industry. That is, it is barely conceivable that more than about 2000 maintenance personnel of any rank would be served per year or that teaching and training sessions including materials could carry a total cost of $1000 each. Therefore, a total direct annual cost of up to $2,000,000 might apply and no combination of lost time allowances, replacement labour, symposia and seminar sponsorships, etc. could bring the total to $10,000,000 per year across the industry. At the same time, the minimum benefits in sight, as confirmed by senior industry staff, should exceed $100,000,000 per year.

Surely, the industry has no better cost reduction prospect in sight.

J. H. Brown and T. M. Evelyn

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MAINTENANCE MANAGEMENT IN THE CANADIAN MINING INDUSTRY:

AN ABSTRACT

Over the past few decades, the cost of maintenance in mining operations has risen dramatically and currently represents the largest single cost category in most operating budgets. To facilitate improvements in the area, CANMET undertook a state-of-the-art review of maintenance in Canadian mines. Though both technical and managerial aspects were considered, it was clear early in the work that shortcomings existed in the management of maintenance systems. The report focuses on these shortcomings.

For the subject review, the total literature on maintenance was first examined in detail so as to develop a framework within which mine maintenance operations could be examined. Subsequently, twelve mining operations across Canada were selected to provide a representative sample of the industry on the basis of geography, scale, commodity and type of operation. Each was visited or examined in some detail. In the process, both the framework devised for the analysis and the state of maintenance operations in the industry were evaluated.

The framework selected divided the numerous aspects of maintenance into two major categories: (a) supporting elements, which improve the effectiveness of a maintenance system but which are not essential to its operation, and (b) essential elements, without which a rational system cannot exist. In addition, three supporting features that can contribute greatly to effectiveness were also considered: computing, analytic techniques and system implementation.

The results of the review represent the industry's own view of its operations as seen in light of the overall framework that was developed. This framework, and the respective survey results, can be summarized as follows:

Supporting Elements of Maintenance Systems

(a) Attitudes toward maintenance operations: these were found to be non-conducive to good performance.

(b) Objectives and Policies as clear and useful statements: they were found to be poorly formulated or close to being non-existent. Also, the need for such statements was not generally appreciated.
(c) Total Life-Cycle Maintenance: it was appreciated as a concept but only partially applied.
(d) Annual Reporting on maintenance: it was found to be deficient.
(e) Management Manuals: these existed but were often outdated or not customized.

Essential Elements of Maintenance Systems

(a) The Organization of maintenance: it reflected the attitudes that maintenance was subservient to production; also only a limited capacity was available to develop and use information to control or develop maintenance capabilities.
(b) Systems and Procedures: they were sound in numerous operations, though applications tended to be poor.
(c) Strategies for preventive maintenance: they were well stated but the corrective maintenance procedures that should accompany them were considered unsatisfactory by the maintenance managers.
(d) Planning and Scheduling: these aspects were often considered unsatisfactory.
(e) Information and Control: these represented the weakest single area.

Additional Features

(a) Computerization: it was common to maintenance operations, but was used to less than maximum benefit.
(b) Analytical Techniques: these were little used.
(c) The procedures for Implementation of maintenance developments were not carefully planned; also provisions for objective appraisal of systems were limited.

In reviewing the completed study it was concluded that (1) the overall framework that was developed does indeed provide a sound and objective basis for analyzing maintenance practices and (2) that the results thus achieved truly reflect the state-of-the-art in the Canadian Mining industry. It is clear that the scope for improvement in mine

maintenance systems is great, and that constructive changes with regard to maintenance could be made at all levels of the industry.

A somewhat more detailed review of the issues reported in the full-scale report is offered in the following sections of this executive summary.

MAINTENANCE MANAGEMENT IN THE CANADIAN MINING INDUSTRY -- AN EXECUTIVE SUMMARY

1.0 INTRODUCTION

Historically, mining has been an aggressive industry oriented toward and managed to take advantage of new mineral discoveries, new processes, new methods and new equipment. That pattern has resulted in the industry's development of large and sophisticated operations, a pattern that has existed in Canada as elsewhere in the world.

More recently, however, increasingly competitive mineral markets have caused Canadian operators to scrutinize their production costs closely. They have found that maintenance costs have risen both proportionately, and in total, with the change in the industry's operating pattern. The subject report deals with the management of, and hopefully the reduction of, those maintenance costs.

The focus on maintenance is an understandable result of the industry's evolution. When mining was a labour intensive industry employing uncomplicated and small scale equipment, maintenance costs constituted only a modest portion of total operating costs. However, as operating scale and sophistication increased, the operating labour components of total costs diminished but both the materials and labour components associated with maintenance rose. Currently, maintenance-related costs are the largest single cost category on many properties, though, until recently, they had received little intensive examination.

It is noteworthy that the rise in maintenance costs was not appreciated by educational institutions or the professional societies either, as their relative remoteness

from operating problems might have permitted. Especially, the need for changes in preparation for effective maintenance management was not sensed, even while programs to better qualify tradesmen and to develop special equipment were being encouraged by governments and the industry. In general, only special maintenance services, including data collection systems and the like, were developed. These served primarily as consulting services, to satisfy the most pressing needs of the industry. It is likely that the expansion in scale and sophistication associated with rapid market growth and rise in inflation overshadowed a need for basic developments in maintenance.

In organizing the CANMET state-of-the-art review[1*] of maintenance in Canadian mines, both technical and managerial aspects of the field were carefully considered by the authors. While technical elements were generally found to be available, albeit used to little advantage, major deficiencies were identified in certain managerial aspects. In retrospect, while these shortfalls had probably been sensed by management, the previous paucity of reliable criteria or gauges for evaluating the managerial aspects of maintenance made it very difficult to isolate specific problems and to consider them on a quantitative basis. In any case, the CANMET-sponsored review began with development from the literature of a framework for the analysis. That framework was used subsequently in conducting and interpreting field examinations.

For this executive summary of the report, the policies and requirements that were identified for the evaluation are noted first; subsequent chapters outline the dominant aspects of the evaluation and the final chapter summarizes the results of the full-scale review.

* Raised figures refer to reference at the end of the text.

1.1 The Need for Organized/Planned Maintenance

For small and uncomplicated production equipment the cost of providing backup units or of repair-at-breakdown has been reasonable; for high-productivity, sophisticated equipment, redundancy is uncommon and both downtime and breakdown repair costs are high. Means for minimizing both downtime and breakdown repair must be found and maintenance management to this end has become a necessity. The issue is not whether to establish management systems with this orientation but to appreciate the factors which must be accommodated in doing so.

First, the dominant requirement of contemporary maintenance management is the degree of planning that is involved. This is illustrated by the organization model of Figure 1 in which the range of information sources, analytical processes, decision centres and action groups that must exist in one form or another are assembled into a control unit. Depending on the size of the organization, the management system in use and the personnel involved, this control unit may be only a few people or it may be a large group. However all functions represented should exist if minimum maintenance costs are to be achieved. The range of skills and capabilities that are required of an effective control unit are unlikely to exist in a single individual, nor would most organizations seek dependence on one such person. Neither can a larger control unit than necessary be justified. Instead, an efficient organization must be designed to satisfy the requirements for any one operation.

Second, since the cost of unproductive systems is not acceptable in most operations, almost any means for minimizing downtime must be used. Therefore, practices such as performance monitoring, before-failure-repair, condition-

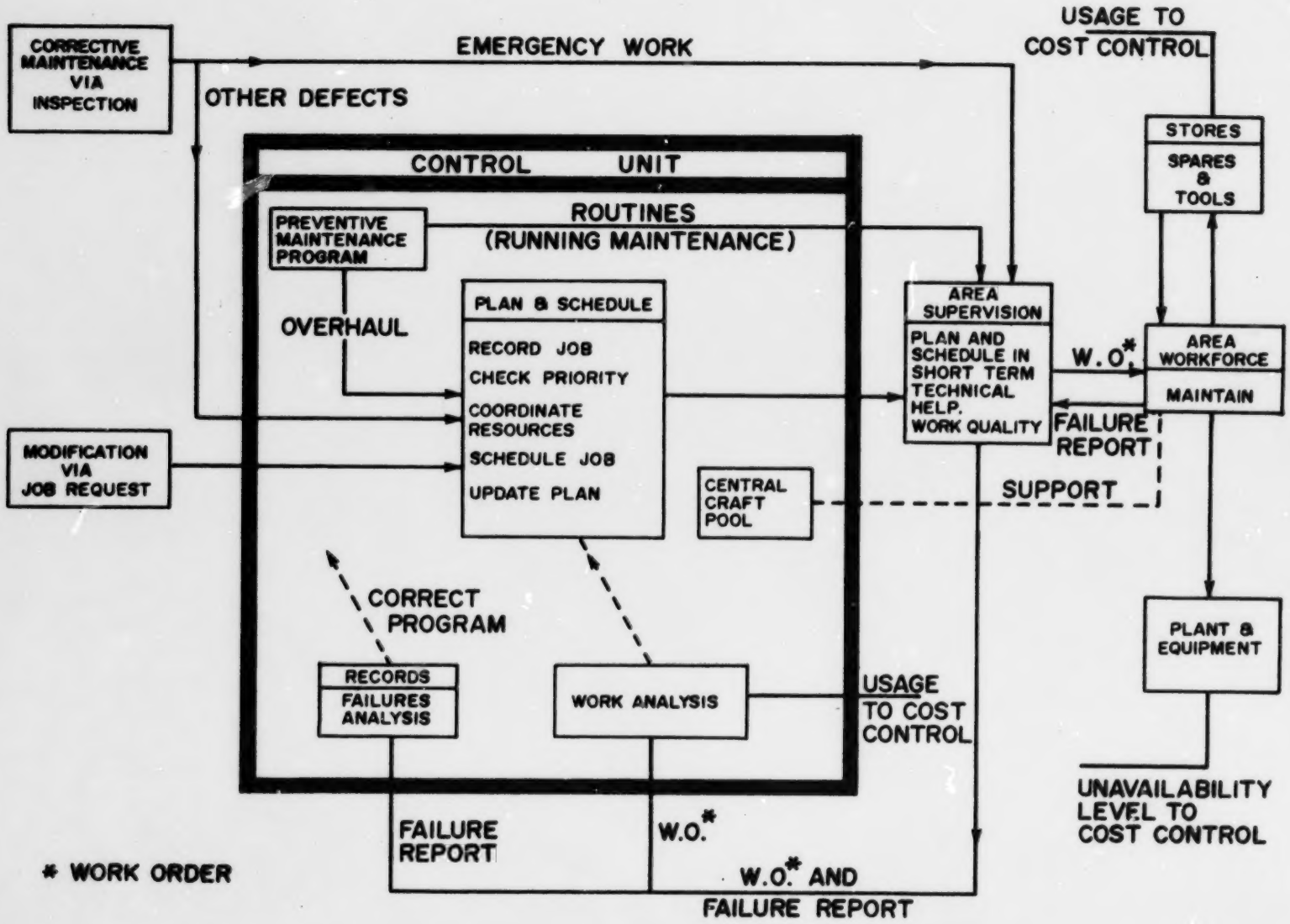

Figure 1: MODEL OF A MAINTENANCE MANAGEMENT SYSTEM

based maintenance, non-destructive testing and so on are essential maintenance management approaches. In fact though, their effectiveness depends on their administration. Even with computerization, significant management skills and appropriate organizational policies are essential.

The combined effects of managing maintenance to maximize planned work can be illustrated as in Figure 2, which is a graphical summary of published analyses of planned maintenance costs in mining and other industries. Briefly, the curve establishes that maintenance costs are greatest when planning is minimal and that cost reductions of about 25% should be achieved if 80% of all maintenance work can be conducted on a planned basis. No evidence has been found to suggest that the potential for planned maintenance is less in mining than this curve suggests, and it is a common comment in the industry that mining maintenance is basically crisis oriented. In that light, this curve can be regarded as a strong indication that a major cost reduction potential exists in the maintenance aspects of Canadian mining.

1.2 The Elements of Maintenance Management

To permit effective examination and evaluation of maintenance systems it is convenient to categorize the elements of the field as essential to or supporting of good management. On this basis the elements of interest can be taken in mining as in other industries, as follows:

Supporting Elements

- Attitudes
- Objectives and Policies
- Total Life-cycle Maintenance
- Annual Reporting
- Management Manual

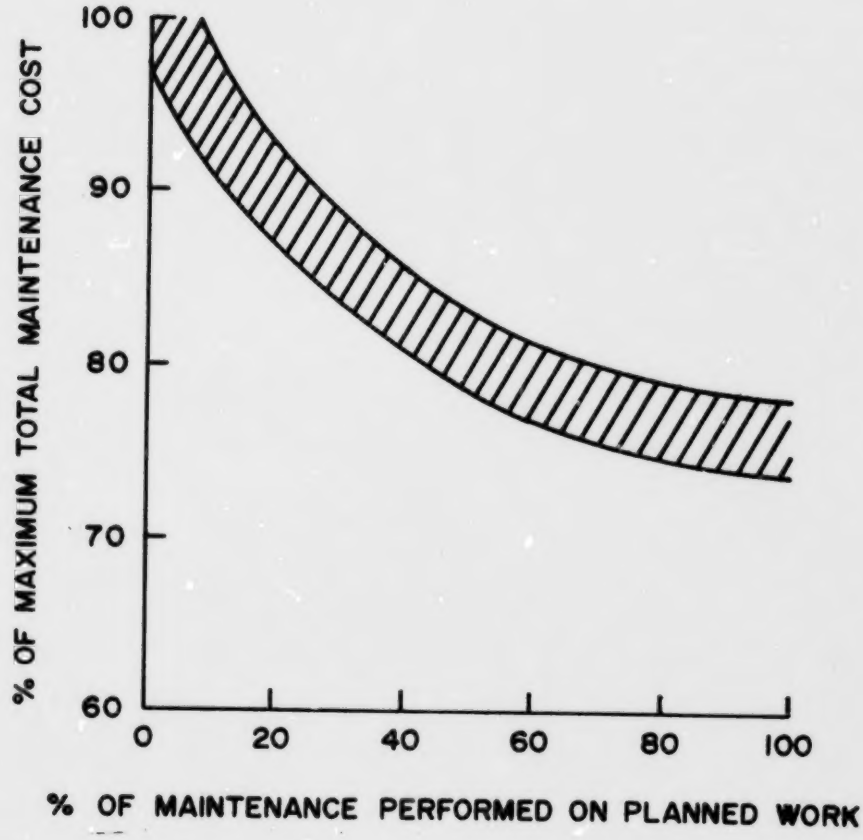

Figure 2: EFFECTS OF PLANNING ON MAINTENANCE COST

Essential Elements

- Organization
- Systems and Procedures
- Strategy
- Planning and Scheduling
- Information and Control

In addition, features such as computer applications, analytical techniques and implementation approaches can also be classified as control features; they should therefore be included in an overall examination.

Of course, the distinction between essential and supporting elements lies in the capacity of management to operate in their absence. Lack of an essential element will ensure failure; lack of a supporting element will merely lower effectiveness. However a decision to neglect or de-emphasize a supporting element should be made only after an analysis of the system, not before. Accordingly it is appropriate to include all supporting elements in an evaluation system and to use them in evaluating a given operation. To emphasize this point the supporting elements are presented first in this outline.

For this report, supporting elements are outlined together in Chapter 2. The essential elements are treated in more detail in Chapter 3 through 6 with Strategy and Planning and Scheduling combined in Chapter 5 because of the close relationship between these elements. Additional features are treated in more detail in Chapters 7 through 9.

2.0 SUPPORTING ELEMENTS

The supporting elements of a maintenance system can be grouped together under a single identity, viz, the environment. On this basis it is not necessary to further explain their relevance, since the management principle that the environment of an organization must support its operation is well known. However, in mine maintenance the changes in the industry in the past few decades have altered radically the nature and role of the maintenance activity. For this reason it is at least desirable to recognize the factors that contribute to the environment in evaluating contemporary mine maintenance management practices.

While identifying only the previously listed five features of the environment as supporting elements, it is assumed that the operating policies of the entire organization are also applied to maintenance. For example, the services of personnel, accounting, medical and other departments are as essential to maintenance as to any other portion of the property and need not be considered here separately. Conversely, lack of access by maintenance personnel to services, procedures or operating arrangements such as a bonus system used by others may be a source of contention. However that prospect, too, is outside the context of this report.

2.1 Attitudes

When maintenance consisted only of repairing simple tools, and production depended on the continuity of manual labour, the maintenance role was legitimately subservient to production. However, in most current mining operations, production labourers are users of heavy equipment and the effectiveness of their time greatly depends on their ability

to use that equipment effectively, and on the performance capacity of this equipment. In that context it might be argued that the dominant interest should be centered upon the equipment. In fact, there is no longer any real basis for regarding either maintenance or production personnel as being subservient. It follows that the management and working attitudes established in a period when primary concern was for production labour may now be out of place in contemporary operations.

It will also be appreciated that the attitudes of consequence are not solely those of the maintenance organization, either of their managers or of their tradesmen. The attitudes, perceived or real, of production personnel toward maintenance personnel also bear heavily on the cooperation that must exist for optimization of productivity. To that extent at least, the attitudes of senior corporate management to relationships that prevail are fundamental, especially since changes in maintenance activity are generally still underway in the industry.

2.2 Objectives and Policies

Another well-established principle of management has objectives and policies of the organization clearly established for all. Yet, again, changes in maintenance organization activities may not have been identified, clarified, confirmed, or accommodated in a property's objectives and policy statement. Especially, in the light of the increasing cost and emphasis on maintenance, the matter of attitudes identified above may require revision or, at least, confirmation of priorities.

In addition, the introduction of maintenance planning methods may require that the corporation establish policies with regard to capital expenditures that incorporate new

selection criteria. For example, repair/replace decisions may require defined policies vis-a-vis discount rates and write-off periods that bear heavily on data collection and job evaluations. Similarly, decisions on major issues such as maintenance shutdowns, should be based on clear policy and objective statements that account for markets, cash flows, and other investment requirements that are senior to property management.

2.3 Total Life Cycle Maintenance

Though maintenance costs are generally identified with the operating life of equipment and systems, they are in fact influenced by experience and procedures that occur both before and after the operating period. This feature of maintenance is illustrated conveniently by the information flows shown in Figure 3 which constitutes a flowchart for total life cycle maintenance. Figure 3 indicates for example that maintenance operations can benefit from operating experience if that experience is evaluated and used in planning, designing and manufacturing the equipment -- just as it undoubtedly is used in evaluating and selecting replacement items and should be used in planning current maintenance work.

In fact, the logic of Figure 3 is indisputable and it is somewhat puzzling that the subject must be raised at all. However there is currently only limited communication between mine maintenance staff and equipment suppliers. Such communications as do exist tend to be between the suppliers' sales representatives and those who establish specifications for equipment, nominally the engineering and operating staff. The latter tend to be oriented toward operating and production characteristics, and not toward maintenance.

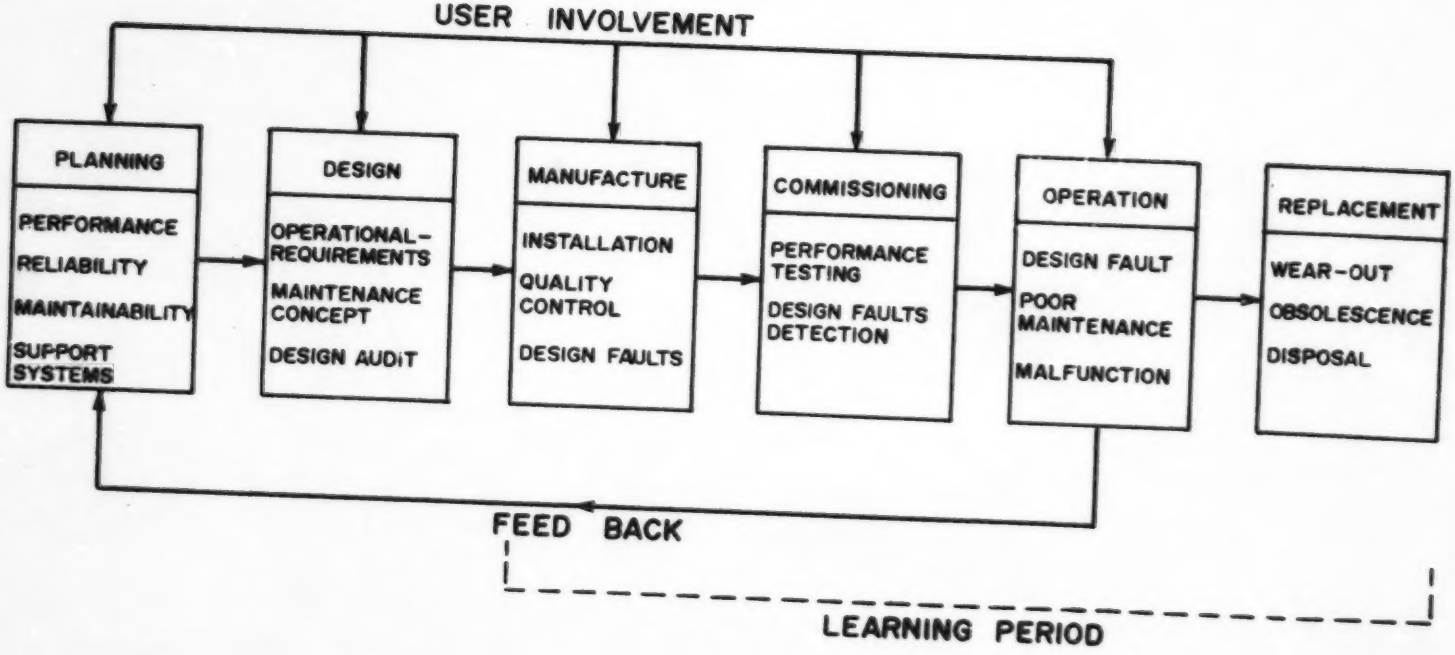

Figure 3: RELATIONS IN TOTAL LIFE CYCLE MAINTENANCE

2.4 Annual Reporting

It is a necessary corollary of an approach which has maintenance management focussing on planning that a regular formal report on maintenance must be prepared. Certainly, it is reasonable to expect a regular formal accounting of a major cost centre and to expect that report to deal with:

- long range plans,
- capital investment programs
- performance evaluations
- cost evaluations.

Equally clearly, the basic message of that report should be directed at the senior corporate levels where the same issues are a continuing routine concern.

2.5 Management Manual

In parallel with the requirements for policy and objective statements and for annual reporting, it is a common basic management requirement that a management manual exist for a maintenance system. That manual should set out the procedures, flowcharts, sample forms, job descriptions, performance measurements, control indices, and so on, that constitute the system by which maintenance is managed. Moreover, the manual should be updated regularly to ensure both its utility as a reference in case of emergency and as a training tool in staff development.

From a different point of view, if there is a decision to seek improvement in the performance and productivity of a maintenance organization, an elementary early action must be to establish clearly, and in some detail, the working procedures of the specific organization.

3.0 ORGANIZATION

If no changes had occurred in the Canadian Mining industry to affect the role of maintenance, the maintenance activities might not be a subject of corporate interest. However as outlined earlier, a major change has indeed occurred, and that change has not been widely accommodated in maintenance organizations, as will be shown later. Consequently an examination of this essential aspect of maintenance is required.

3.1 Corporate Maintenance Relationships

The need for objective corporate policy statements with respect to maintenance has been outlined. However, it will also be appreciated that the generation, transfer and continued awareness of those policy statements require that a continuing identity for maintenance exists in the corporate structure. To establish, retain, and/or confirm this identity at least two features must be examined:

- The specific personnel and offices by which maintenance is represented,

- The relationship of the maintenance voice to operating and technical counterparts.

More important, and again perhaps as a corollary to these two functional relationships, is the establishment of (1) a professional preparation for and (2) a professional identity for maintenance management. It is still widely accepted that a maintenance manager is a former master mechanic. While he may indeed possess the necessary capac-

ity, there can be no doubt that preparation as a master mechanic alone is in no way an adequate preparation for the management of a contemporary maintenance organization. Neither does an academic system for such a preparation exist yet, either inside corporate structures or elsewhere. That unsatisfied management requirement is clearly a corporate concern that needs to be addressed forthwith.

3.2 Department Organizations

The features of maintenance department organizations must resemble those that apply to any other department of an operating group. Unfortunately there is little evidence that they have been examined as thoroughly within the industry as might be desired. Briefly these desirable features can be summarized as follows:

- A well defined structure, specifically organized for the property being served
- Well defined functions for all levels of this structure
- Cleary defined authorities and responsibilities
- A clearly defined control unit that ensures planning, and completion of both supervision and administrative duties
- Training provisions
- Adequacy of manpower and supervision
- Appropriate functional communication links with operating groups

- Clear and consistent personnel selection and promotion procedures

- Management accountability provisions

It might be noted specially that such training programs as already exist on a property may not be particularly relevant to maintenance operations because of the recent major changes in the roles of maintenance, as already mentioned.

4.0 SYSTEMS AND PROCEDURES

It was pointed out earlier, and illustrated in Figure 1, that an effective maintenance organization must accommodate much more information flow and decision making than can be expected reasonably of any one individual. It follows that the performance of a control unit, however organized, must depend on the systems and procedures that are to be established. To evaluate these, five basic facets of the system must be identified and examined:

- Data generation and records, i.e. the paperwork,
- Stores operation and control
- Standards development and application
- Budgeting
- Critical problem reporting and analysis.

Brief outlines of each may clarify their uniqueness in the maintenance environment.

4.1 Paperwork

Because there is no visible product from a maintenance organization, there is no material flow by which to sense needs, timing and action in the system. Instead, the organization must rely on an information flow from which those needs, timing and actions can be sensed and implemented. This information flow arises from such items as:

- equipment inventory lists

- equipment data cards or files
- check lists and service sheets
- work orders and work reports.

For effective maintenance management, these items of paperwork are at least as important as the completion of the work itself.

4.2 Stores Operation and Control

The primary role of stores on most mining properties is the provision of maintenance material but, for several reasons, stores are not part of the maintenance system itself. Nevertheless, to minimize inventory and maximize utility a close and confident relationship, as well as a reliable communication system between stores and maintenance is essential. Areas of common concern must include:

- quantity and quality of stock
- classification of stock
- materials delivery to job sites
- obsolescence
- purchasing procedures and schedules

4.3 Standards

It is a common argument that maintenance standards are impractical until causes of failures are known. That approach is inappropriate for a maintenance management

system because the goal of the system, as indicated by the curve of Figure 2, is to conduct work on a planned basis. Moreover, even for unplanned repairs, a wide range of component-related repair approaches, unit replacement systems and the like can minimize the unplannable elements of the work. As a result, the essence of low cost management must include the establishment and improvement of standards and the ability to use and improve them; the concept of avoiding them is quite impractical. It follows that a basic appreciation of statistical concepts and methods is fundamental to effective maintenance management.

4.4 Budgeting

Budgeting is not realistic for unplanned maintenance. As a result the historical approach to budgeting in maintenance operations has been largely a process of relating historical data to anticipated production, with due allowances for special events that could occur either preceding, or during the proposed budget term. For planned maintenance the basis of projection is firm and both measurements and performance evaluation can be realistic. As a result, a continuous budget review and control at all levels of the organization is quite possible; it can provide one tool for monitoring maintenance performance.

4.5 Critical Problem Reporting and Analysis

Just as disaster analysis aims to prevent repetition of the disaster, or at least to minimize the effects of any repetition, an analysis of emergencies and of all other critical problems must be carried out both to prevent any recurrence and also to improve the capacity to deal with similar future events.

5.0 STRATEGY - PLANNING AND SCHEDULING

Though strategy, as well as planning and scheduling are separate features of maintenance management, it is convenient to treat them together. Briefly, strategy is the specification of maintenance work requirements, relative priorities, timing and approaches; planning and scheduling are the procedures that ensure the timely completion of work. Together they should establish control of maintenance systems and minimize cost for the total function.

5.1 Maintenance Strategy

The basic aims of strategy are the resolution of what items to maintain and when and how to maintain them. The decisions must reflect criticalities to the systems, cost to the operation, availability and practicality of repair and replacement, reliability of items and so on. Basically, two classes of work are involved:

Preventive maintenance is that work that can be done without interference with production on a reasonably flexible basis. It may include such elementary work as lubrication and routine service, a range of monitoring activities, as well as a wide range of sophisticated analytical or diagnostic work. In total, it should minimize failures that can cause shut-downs and give maximum scope for planning maintenance activities.

Corrective maintenance is, by definition, both random and dynamic in nature but its costs and effectiveness are determined by the availability and execution of planned procedures for whatever failure occurs. In a real sense, the establishment of corrective maintenance strategy parallels the process by which a fire department anticipates

fire sources, distributes its resources, and prepares its personnel for inevitable conflagrations. The alternatives to corrective maintenance strategy with planning and scheduling is a lack of control and preparation with which to handle a crisis.

5.2 Planning and Scheduling

These two functions, by which strategy is implemented, are the core of a truly cost-effective maintenance system, and, though separate technically, they are difficult to separate in practice. Moreover, they must be consistent with the needs and limitations of a particular operation while also conforming to corporate policies; moreover they must be flexible enough to accommodate the random requirements of corrective maintenance.

The dominant feature of planning and scheduling is the need for trained capable personnel and effective information systems, in addition to a clear organization and well-established procedures.

6.0 INFORMATION AND CONTROL

It was noted earlier, while outlining the foci of the relevant systems and procedures, that proper information flow is essential in a well-planned maintenance system. The present concern is for the specific sources and uses of information that must exist; the flowchart of Figure 4 illustrates the flow and uses that can be anticipated.

6.1 Elements of Information

A maintenance information system can be regarded as having four elements with specific purposes as follows:

- data acquisition, to collect sufficient reliable information
- data organization, to compile information in formats that will make it useful for the various purposes involved
- data analysis, to screen and review information to establish useful trends and patterns
- data feedback, to supply specific information and the results of analyses to those who can use them effectively in maintenance control

Clearly too, the assembly of appropriate data and decisions into records and reports are basic functions of the information system.

6.2 Maintenance Control

As indicated in Figure 4, control in a maintenance system can be composed of two parts; one is the immediate management of corrective and preventive maintenance, the other is the work of designing and improving the maintenance program itself. This second activity is vital to maintenance because, as equipment ages, it is replaced or is developed and, as the system itself matures, the problems change and the entire system must be updated and probably modified. Both in routine operation and in updating it is

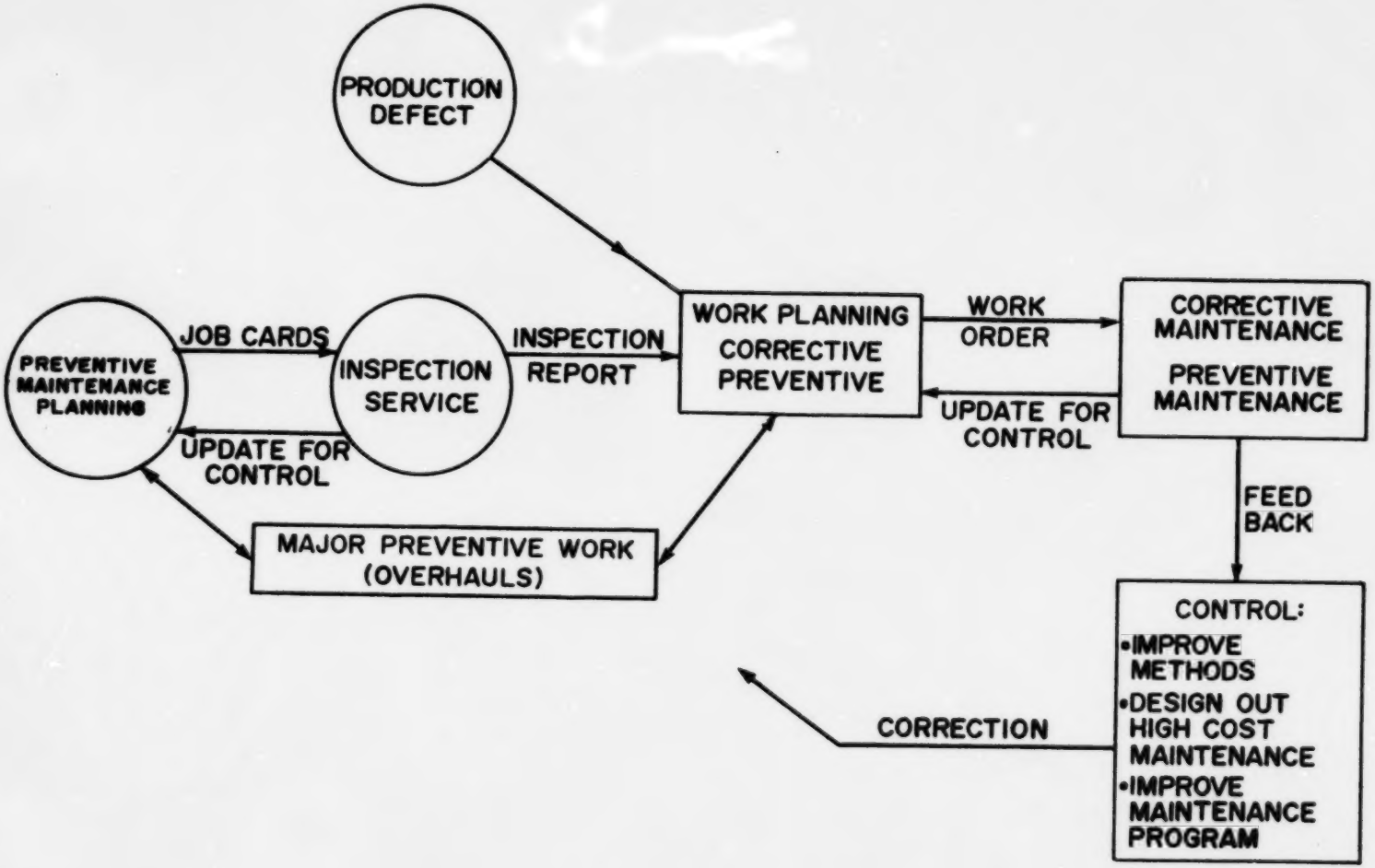

Figure 4: INFORMATION FLOW IN A MAINTENANCE SYSTEM

clear that criteria and suitable measures of effectiveness are required.

Performance measurements in maintenance have used labour time, costs, backlog and other direct gauges as well as a range of work indices; the selection of specific measures for any organization depends on the goals, systems and policies of that particular operation. However, for any measuree to be effective they must be well understood and appreciated by those who are most affected by them and, also, the data upon which the measures are based must be respected. It follows that clear and visible commitments to effective maintenance must exist throughout the organization.

7.0 COMPUTERIZATION

No mention was made in the foregoing outline of information and control features about computerization, though it is unlikely that a contemporary maintenance organization of any appreciable size can function effectively without computing facilities. However, early attempts to use computing in maintenance tended to fail because they were not established to accommodate maintenance organization requirements so much as to use already available computing services. In this light it is important to mention the three major elements of computing systems that are significant in maintenance operations.

First, the basic role of computing in maintenance is to collect and organize data and to make information available. The dominant concern must be that the original data are valid and relevant; invalid and irrelevant data merely load the processes and diminish the value of both the essential data and the information generated from them. Also they destroy user confidence in an otherwise solid system.

Second, the computer must provide sufficiently rapid access to enough relevant information so as to make maintenance planning and scheduling a firm management function. That is, by using the computer, decisions and assignments can now be made confidently on the basis of specific equipment records, specific requirements, high probability events and so on.

Third, the computer must provide sufficiently rapid access to parts lists, inventory and job procedures so that job planning and the related functions of the stores and purchasing departments can be integrated effectively with the maintenance operation itself. Facility in proper report preparation, status reviews and so on is also an inherent necessity.

At the same time it should be clear that the effectiveness of the computer in maintenance depends more on the existence of a sound understanding of the maintenance organization, its policies and its goals, than on the intricacies of the computer hardware. If practical, it will

be much better to have an effective manual information system in operation, before introducing the computer to a maintenance organization. In any case, it will be counter-productive to allow the power and value of the computing facility to dominate the more fundamental requirement that the staff fully understand and appreciate the needs and goals of their maintenance operation.

8.0 ANALYTICAL TECHNIQUES

In industries such as airlines where failures can have catastrophic effects, it is usual to install redundant systems and to use numerous analytical techniques in developing and planning maintenance organizations and activities. It is doubtful that either the level of redundancy or the sophistication of airlines could be justified for mining operations. All the same it is, at least, prudent to examine the opportunities for beneficial use of those techniques in mining.

Analytical techniques, including operations research, reliability statistics and so on, are related to total life cycle maintenance and the relationship can be illustrated in terms of the life failure patterns of equipment shown in Figure 5. Basically, all equipment shows a failure pattern such as illustrated and the purpose of analytical techniques is the determination of the state of the machine or component relative to this pattern. The goal is the determination of the level of the maintenance that can be justified and expected for the equipment at any particular point in its life. Specific problem areas in equipment can be identified thereby and repair-before-breakdown practices can be significantly enhanced.

The essential feature of analytical techniques in mining, at this writing, is not the sophistication involved nor the level of analytical expertise that must be developed and supported. Instead, it is the appreciation that this prospect exists and that the introduction of a sound organization with clear systems and an effective information capability can make it available. Moreover, the full range of analytical techniques includes highly pragmatic simple ones as well, that can always be used by the competent management who will be part of an effective system anyway. As a result, a clear corporate commitment to maintenance carries with it the opportunity to develop and use much more sophisticated and powerful tools than those that are basic to normal maintenance operations.

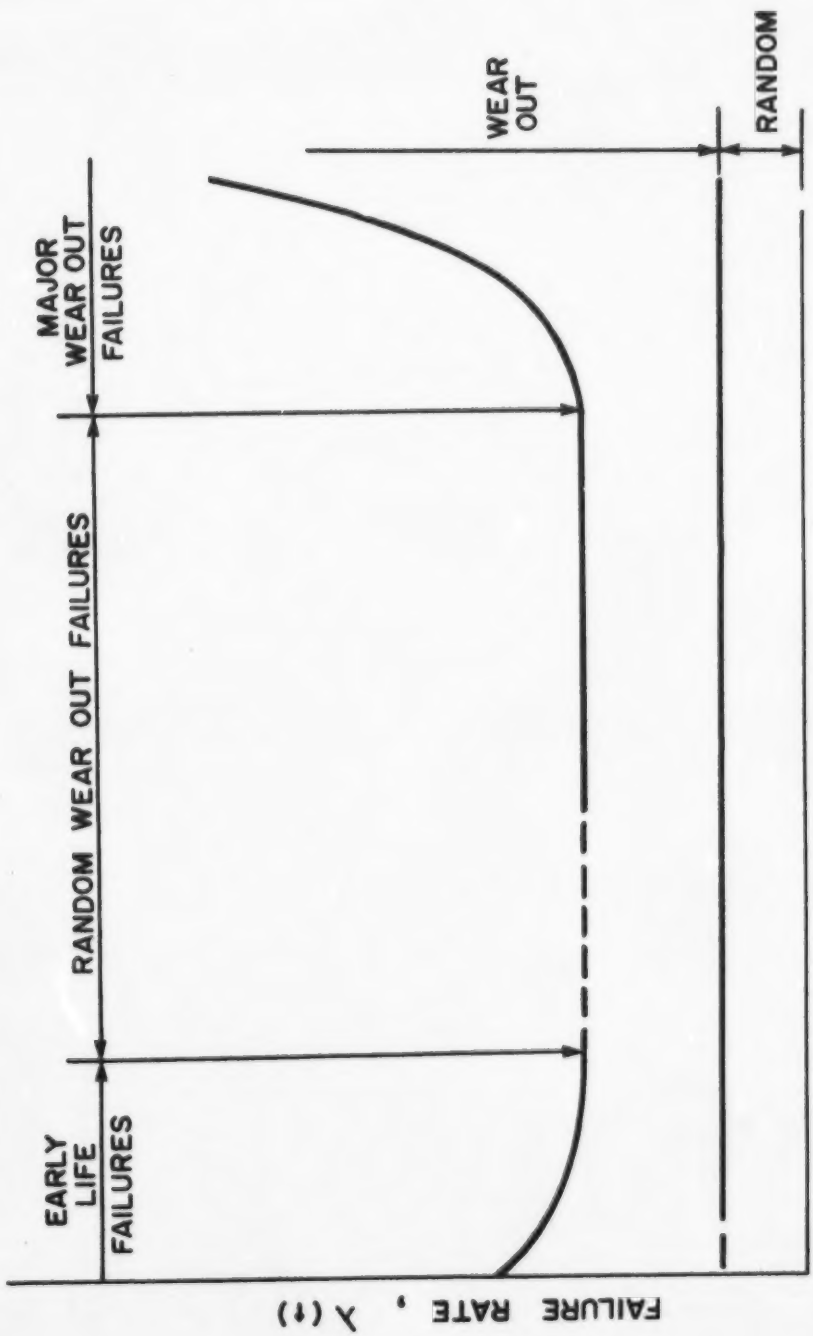

Figure 5: COMPLETE LIFE FAILURE PATTERN FOR EQUIPMENT/COMPONENT

9.0 IMPLEMENTATION OF A MAINTENANCE MANAGEMENT SYSTEM

It was noted earlier that there is no product for a maintenance system and that the system depends on a flow of information. This feature is an essential consideration if significant changes in an existing maintenance system are to be undertaken.

As a minimum it is clear that an effective maintenance system must be characterized by constructive attitudes towards maintenance, respect for data generation and use, and an appreciation of the sophistication of the system. Moreover, the greater the change in the system the more these features may be in conflict with earlier practices and attitudes. As a result, the system change or replacement must provide for

- involvement at all levels of corporate management
- involvement at all levels of management on the property
- awareness of the policies, goals, responsibilities and time frames of maintenance
- creation of a positive attitude toward maintenance
- visible commitment to professional maintenance management
- accountability in the maintenance system
- credible support for the changes.

In short, the change must be organized, not merely localized or superficial.

To effect changes such as these it is also clear that (a) they cannot be introduced too rapidly, that (b), significant educational programs may be involved and (c) that vacillation in the implementation program could be disruptive or damaging. Instead, the implementation program must be carefully planned, cautiously introduced and consistently prosecuted. Especially, corporate reinforcement of the changes must be visible to ensure the continuity of the development effort. Fortunately, the benefits that are available are more than sufficient to justify the effort.

10.0 THE STATE OF MINE MAINTENANCE MANAGEMENT IN CANADA: AN OVERVIEW

To establish the state of the industry's maintenance activities in early to mid 1983, the elements outlined in the foregoing sections were reviewed and evaluated with mine staff. Twelve operations were selected for review with the assistance of CANMET. They were selected to provide a test of geographical distribution as well as of scale and technical variations within the industry. As a result, the proposed system of analysis was evaluated in terms of its acceptability and relevance to maintenance operations. Simultaneously the state of the industry as seen through the eyes of the mine staff itself was also established.

It was found that the analytical system was grasped quickly by staff and that it permitted clear evaluation of independent elements in all types of operations. Therefore, the evaluation results are presented, confidently, as those of the industry, and not as those of the investigators, though the investigators' own impressions are consistent with the responses reported. Results were reviewed with CANMET staff as the field investigation progressed to ensure widest practical coverage of individual topics.

Although presented in an earlier section, the results are again presented hereunder in a little more detail. For convenience the same order and association is used as was followed in presenting the elements of the overall framework.

10.1 SUPPORTING ELEMENTS

Even though attitudes were in the process of changing at the time of the full-scale review [1] in 1983, reasons still exist today to question top management's attitudes toward maintenance. Undoubtedly too, there is still considerable concern at the operating levels that only a limited interest in, and appreciation of maintenance exists at corporate executive levels.

Objectives and Policies were found to be close to non-existent. Generally they were assumed to be self-

evident and, where they did in fact exist, they lacked detail, clarity and specific relevance.

Total Life-Cycle Maintenance was generally appreciated as a concept but only partially applied. There was little ongoing liaison between companies and suppliers; suppliers' visits to operations were restricted to sales and user training, not to maintenance liaison.

Annual Reporting on maintenance usually consisted of a small section of the overall operation's report and, more often than not, the information was overloaded with production figures.

A Management Manual was present in most systems but was either outdated or not customized to the system's needs.

10.2 ESSENTIAL ELEMENTS

It was found that organization of maintenance had received little attention. Maintenance was still regarded as subservient to production and there was dissatisfaction with the level of support and attention given to it. Control units, in the sense identified here, were generally missing or were, predominantly, clerical functions. Also, craft training was primarily informal and management training was almost totally lacking.

Systems and Procedures were sound in a number of companies but applications tended to be poor. Specifically, work orders were poorly designed or poorly engineered. Stores/maintenance interfaces tended to be poor and there was a general lack of work standards.

Strategies for preventive maintenance were well-stated but few companies had established good corrective procedures. Many maintenance managers were generally dissatisfied with the results of preventive maintenance work and identified lack of production cooperation, lack of historical data, poor analysis of available data, limited use of diagnostic techniques and poor updating as contributing problems.

Planning and Scheduling were often considered un-

satisfactory, too often merely involving clerical work, or else asking too much of the maintenance foremen, who were already pressed for time. Lack of personnel of the right calibre was often identified as the basic problem.

Information and Control were, by far, the weakest of the essential elements required and looked for. Most companies had fair information systems but very few made effective use of the available data to effect satisfactory control.

10.3 ADDITIONAL FEATURES

Although computerization was common to most maintenance organizations, it was used mainly for stores inquiries, information storage and only to a limited extent for maintenance scheduling. Few companies were prepared to use their computing facilities to maximum benefit, probably because the training and experience requirements of the system had not been fully appreciated.

Generally speaking analytical techniques were little used, due to a lack of suitable personnel.

Implementation was not practiced as a carefully planned process. Many systems had been introduced with the affected personnel totally unprepared to handle them; moreover, provisions for objective performance appraisal were very limited.

10.4 EVALUATION VALIDITY

Though no doubts exist in the minds of the authors as to the validity of the results of this investigation, it is inevitable that weaknesses exist in any state-of-the-art review. In particular the sensitivity of the results to two weaknesses should be appreciated:

First, it is stressed that the review was academic only in the sense that it was conducted by an academic institution. However, the analysis of the literature was an analysis of reported operating systems and the comments were those of the industry itself. These may represent less than fully relevant and informed sources for a mining industry

wide analysis.

Second, the sample, though limited, represents some ten percent of Canadian mines and mine production with a broad coverage of other aspects as well (eg. that of geography, type of mine, etc.) The report's relevance to the entire industry can therefore be taken as an excellent first approximation.

10.5 CONCLUSION

The conclusion is inescapable that the Canadian mining industry has considerable room for improvement of its maintenance operations, particularly as regards to some of the management aspects.

Much of the improvement that could be suggested would deal with matters that are exclusively the responsibility of the individual companies, as opposed to systems and hardware-oriented improvements that could be purchased or injected by outsiders.

Moreover, the scope for improvement in mine maintenance systems does not include maintenance operations alone; changes are indicated at all levels from corporate offices to the maintenance job.

REFERENCES

1) "A Review of Mine Maintenance in Canada - Prepared for Canada Centre for Mineral and Energy Technology (CANMET)", T.M. Evelyn and J.H. Brown, Queen's University, Kingston, Ontario, under DSS Contract 20SU 23440-3-9094, 275 pp. (November, 1983).

APPENDIX

PROPOSAL FOR FUTURE WORK

The state-of-the-art review concluded that (a) no major technical effort is required in support of maintenance activities in the mining industry, but, (b) significant shortcomings exist in the management aspects of the field. The shortcomings include both inappropriate attitudes toward maintenance and deficiencies in the preparation of maintenance managers. Moreover, these faults appear at most or all levels of the industry, from corporate offices to job-sites. If the industry is to improve its maintenance services and lower the costs of those services, it is clear that an extensive educational/preparatory program will be necessary. This proposal outlines one approach by which such a program could be established.

A program to develop maintenance management could, conceivably, be organized in association with CANMET, with consultants practicing in the field, or with one or more universities; it might also be organized as a new and independent agency equipped to bring these existing interests and capabilities to bear on the work. This last option is urged on the grounds that CANMET, the consultants and the current teaching institutions are not qualified for or oriented toward the required combination of teaching in industry and pragmatic development. Instead, a specifically oriented agency should be sought that includes means to ensure industry input to the program, and can also enlist the aid of all concerned parties.

At the same time, it would be premature to propose a detailed structure for the new program now though it will, obviously, be dedicated for the most part to the prepara-

tion, presentation and distribution of a wide range of teaching and training services. For details of form and function to be meaningful, the industry's commitment to the concept along with a measure of the detail that will be desired should first be established.

Therefore this proposal is for a staged establishment of the desired service.

Briefly, the proposed Maintenance Management Development Program is based on the following assumptions:

1. That commitments to an educational program oriented to maintenance management should be confirmed by corporate management of the industry prior to detailed planning;

2. That the new program must be able to serve the needs of a dominant majority of properties and companies in the industry;

3. That, in accord with (1) and (2), above, the new program must aim to provide teaching/training services initially for line supervisors and managers, at least; and

4. That the services of the proposed program, including its management must be self supporting.

Under the above premises, it is proposed that the Maintenance Management Development Program be established in three stages as follows:

STAGE I: Executive Identification

This stage will aim to provide corporate level endo-

rsement of the proposed Program's concept. In it, the presidents and/or appropriate corporate officers of the industry will meet in a one-day symposium/seminar at which the nature of the problem identified in the report and the approaches that can be adopted will be presented. In the process, the policies, funding and organizational features of the Program should be developed to the point where a subsequent prospectus of the program will earn prompt formal endorsement by most corporate officers.

It is proposed that the symposium of Stage I be held in Toronto; its budget could be about $10,000.

STAGE II: Manager Evaluation/Design

Subsequent to a successful Executive Identification stage, an intensive symposium/seminar will be organized to permit property managers to meet and plan the specific subjects and general methods to be involved in the Program. In essence, the functional pattern of the new organization will be determined, subjects for early teaching/training services and means for financing the process will be established. Obviously broad representation of the industry will be vital to this meeting.

This stage will require 3 to 5 days and should be held at an appropriate conference centre that can handle at least 30 representatives of the industry. At that level a budget of about $20,000 is proposed.

STAGE III: Staff Instruction

This stage will be the actual operation of the Program. Teaching/training products will include, for example, packaged courses for presentation in conference centres in

convenient locations across the nation, self-study programs for use by individuals, and seminars/symposia on specific subjects in addition to such promoters of maintenance consciousness as posters. In some senses, a training program such as was used and is still in use in developing and maintaining safety programs will be involved.

Courses such as envisaged above, often involve about one week of instruction and budgets of about $10,000 per offering; self-study programs for significant numbers of students generally carry charges of a few hundred dollars per student at most.

If the proposed approach is implemented, the time required for completion of Stages I and II will be about 6 months and the practical implementation of Stage III could begin within less than 1 year. The full benefits of the entire program should be approached within about 5 years after which two patterns can be projected. In one, the universities and colleges will be offering preparation in those aspects that are consistent with their curricula. In the other, awareness and update programs paralleling those of current safety programs will be established for the maintenance area.

It is also intended that the proposed Maintenance Management Development Program be so organized that its evolution to accommodate longer term changes is assured. For that reason, a positive industry linkage is proposed both for the initial organization and for subsequent operation. In that linkage, the Mining Association of Canada and the Coal Association of Canada may have a highly constructive role.